B -06

THE EFFECTS OF DROUGHT CONDITION ON THE FLOWERING AND FRUITING STAGE OF MYCORRHIZAL INFECTED TOMATO VARIETIES

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Abstract

A method used for the development of dry areas or drought condition, is the improvement of soil structure to support the growth and development of crops. Tomatoes have the potential to be developed in dry areas due to its high nutrition, high in demand and easy to be cultivated. The tomato fruit as the main yield that will be harvested, is prone to be affected by water supply to the plant. One of the method used to improve absorption of water is the addition of microorganisms such as mycorrhizal fungi. The interval of irrigation can be used as a simulation of drought. The aim of this research was to observe the effect of mycorrhiza on the development of two tomato varieties, especially the flowering and fruiting stage, with several treatments of irrigation.

The method used was the addition of 4 gr of mycorrhiza per polybag (size 30x30 cm), using Complete Randomized Design. There were 12 combinations of treatments. The treatments were : 2 tomato varieties (Revalina and Martha), 3 interval of irrigation (every day, every 7 days and every 14 days), and 2 treatments of mycorrhiza (0 gr and 4 gr). There were 3 repetitions for each combination of treatments. Observations were done on the number of flowers, initiation of flowering, number of fruits, weight of fruit, number of leaves and root length. The results showed that the addition of mycorrhiza did not significantly affect the flowers or fruits but affected the root length of tomato varieties. The difference in number of leaves, number of flowers, number of fruits, and fruit weight were also caused by the difference in irrigation interval. The two varieties used made a difference in the number of fruits, weight of fruit and root infection by mycorrhiza. Further research must be made on the effect of mycorrhiza on other tomato varieties and fruit quality of tomato.

Key words : drought, flowering, fruit, mycorrhiza, tomato)

INTRODUCTION

In marginal lands, water is scarce and becomes a limiting factor for plant growth and affects productivity. Areas such as sandy coastal areas that are dry and saline can be found widely in Indonesia. Approximately 8 million ha of dry land and 11 million ha of critical land can be found in Indonesia (Haerah dan Jafar, 1993 *cit.* Gunadi dan Subhan, 2007). Drought can affect the morphology, physiology, biochemistry and molecular activities of plants (Muhammad

et al., 2012). One of the strategies in developing marginal lands is to plant crops that have a higher economic value to increase the income of local farmers.

To optimize the use of drought prone areas or marginal lands, the quality of the soil must be increased to support the growth of plants. One method to improve soil aggregation, especially in poor soil, is by adding biostabilizers or using advantageous microorganisms. One type of microorganisms that can be used in improving plant growth in poor soil is the symbiotic fungi called mycorrhiza. Mycorrhizal association has been used to increase the production of several crops, such as in soybean and corn (Yusnaini, 1998 *cit.* Dewi, 2007). It was proven that mycorrhiza was able to increase production in both crops. Mycorrhiza helps in the absorbtion and active transport of water and nutrition. This, in effect, fulfills the need of water for the growth of plant tissues and support the growth of plant (Rapparini and Penuelas, 2014).

Tomato was used in this research as the host plant for mycorrhizal association due to its importance in human diet. One of the most consumed vegetable in the world is tomato which is rich in vitamin A and C (Pervez *et al.*, 2009). There are many varieties of tomato that are sold worldwide. Tomatoes can be differentiated from its type of growth: determinate and indeterminate. Indeterminate growth occurs when the activity of the meristem does not end after producing a fixed number of organs are produced, such as floral buds (Smith *et al*., 2010), while the determinate type stops producing after a certain number of organs are produced

RESEARCH METHOD

This is an experimental research using two varieties of tomatoes (Revalina and Martha) each composed of 12 samples (plants). This research was carried out in the Biology Garden, Fac. Maths and Science, Yogyakarta State University and the Mycology Laboratory, Gadjah Mada University during June-October 2014. The independent variables in this experiment were : tomato variety, dose of mycorrhiza and the watering frequency. The dependent variables were number of flowers, initiation of flowering, number of fruits, weight of fruit, number of leaves and root length. Factorial complete randomized design (CRD) with 3 factors (1) tomato variety (Revalina and Martha), (2) watering frequency (every day, every 7 days and every 14 days) and (3) dosage of mycorrhiza (0 gr and 4 gr per polybag). As control, media without mycorrhiza was used and was watered every day. For each treatment there were 3 repetitions. The plants were grown in the greenhouse to avoid watering by rainfall. The media used consisted of sand, soil and leaf compost (rasio 1:2:2) and the fungi used as mycorrhiza was *Glomus* spp. Other equipments and materials used were analytical balance, ruler, measuring tape, oven, object glass, microscope, labels, digital camera, polybags, plastic string, hand sprayer, plastic mica, insecticides, glue and planting tools. Data was analysed using the factorial ANOVA (SAS programme) and graphics were made using Excel for certain parameters

RESULT AND DISCUSSION

1. Flowering Time and Number of flowers

The number of flowers were observed from 4 weeks after planting. The plants started to produced flower 5 weeks after planting (figure 1.). the number increased and reached its peak with the maximum number of flowers at 8 weeks after planting. The treatment that produced the most flowers was V1M0P1 (Revalina variety without mycorrhiza and watered everyday), followed by V1M1P1 (Revalina variety with mycorrhiza and watered everyday). In those 2 treatments there was no difference in the time of flowering, thus the application of mycorrhiza did not affect that factor. The number of flowers decreased after the 8 weeks after planting as fruits were being developed by the plants.

The number of flower produced by each plant correlates to the photosynthesis occurring

in the plants. If water and nutrients from the soil are optimal for plant growth then photosynthesis can occur at an optimum rate to make the product needed for growth and development of the plant. Water stressed condition for a long period of time can cause a lower number of flowers. A more optimum photosynthesis can affect the development of plant during the generative stage. Thus, factors lowering photosynthetic activity such as water stressed condition can affect the production flowers and fruit in plants (Riszky, 2009). The difference between the varieties used in this experiment may be caused by the different adaptation of the two varieties.Variety Martha is usually grown for middle to high land, thus adapted to a cooler environment. Variety Revalina is a middle to low land variety, thus more adapted to a higher temperature.

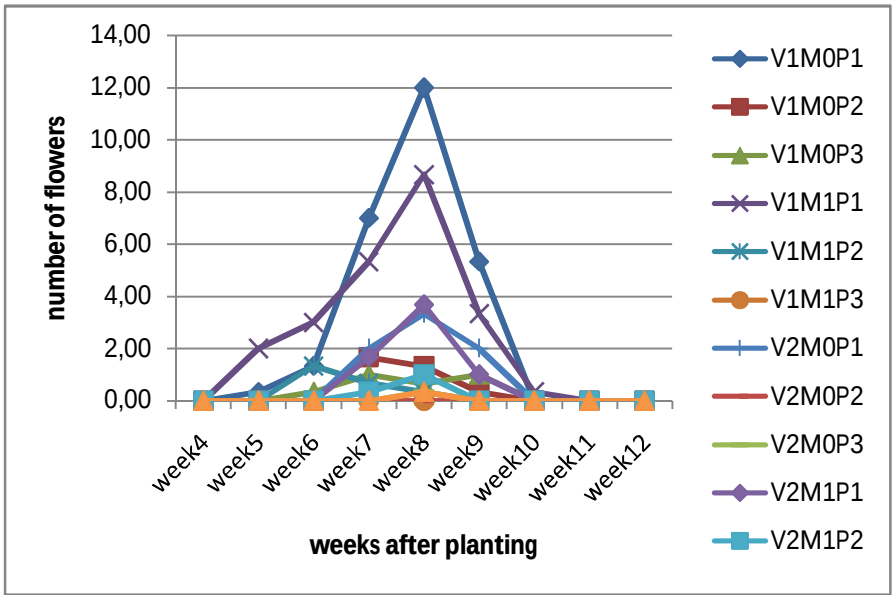

Figure 1. Number of flowers in each treatments

2. Number of fruits

There was a significant difference in the number of fruits between the different watering treatments and between varieties (Table 1). this shows that there was a difference in the ability of each variety to produce fruits. Other than being caused by the different adaptability of each variety to different environmental conditions, the fruits produced by each variety is potentially different.

Table 1. ANOVA of number of fruits

Variable	df	Sum of squares	Mean square	F value	Pr > F
Variety	1	163.54	163.54	18.0	0.0003
Mycorrhiza	1	0.015	0.01	0.00	0.9681
Watering	2	1287.95	643.97	70.87	<0.0001
Interaction (V*M*P)	7	122.05	17.44	1.92	0.1107

Post hoc analysis using Duncan Multiple Range Test (DMRT) was carried out to further analyze the difference between each variety in the production of fruits (table 2).

The result showed that there is a significant difference in the number of fruits between the 2 varieties of tomato. Variety Martha produced less number of fruits, only less than half of the fruits produced by variety Revalina.

Table 2. DMRT of variety effect on number of fruits

Treatments	Mean number of fruits
V1	7.21^{A}
V2	2.94^{B}

Note : Values followed by the same letters (A,B,C) show no significant difference

Analysis using DMRT was also carried out for the different treatments of watering. The results showed that there was a significant difference between plants that were watered every day with those that were water stressed (table 3). However, there was no significant difference between the treatments of watering every 7 days and every 14 days. The water stressed treatments was effective using the 7 days treatments as this can already cause a decrease in fruit production. The average number of fruits produced during the 7 days water treatment caused a decrease to only approximately 10% from the number of fruits in the plants watered every day. This number decreased further in the treatment of water every 14 days which produced only less than 2 % of the numbers produced when watered every day.

Table 3. DMRT of watering effect on number of fruits

Treatment	Mean number of fruits
P1	13.833^{A}
P2	1.50^{B}
P3	0.25^{B}

Note : Values followed by the same letters (A,B,C) show no significant difference

The fruits started to develop 6 weeks after planting (figure 2), that was 2 weeks after the plants started to develop flowers (figure 1). For treatments of watering every day gave higher number of fruits in both varieties. However, variety Revalina produced a higher number of fruits. Its number continue to rise and in 12 weeks reached 19 fruits in the treatment without mycorrhiza and watered every day. From the ANOVA there can also be seen a significant difference in the number of fruits between the two varieties. Thus there must be a significant role of the difference in the genotype in the production of fruit. The environmental effect from the difference in the availability of water was also significant but its effect was the same in both varieties, that is by reducing the ability in producing fruits. However, the interaction between the 3 factors (mycorrhiza, watering and variety) was not significantly different.

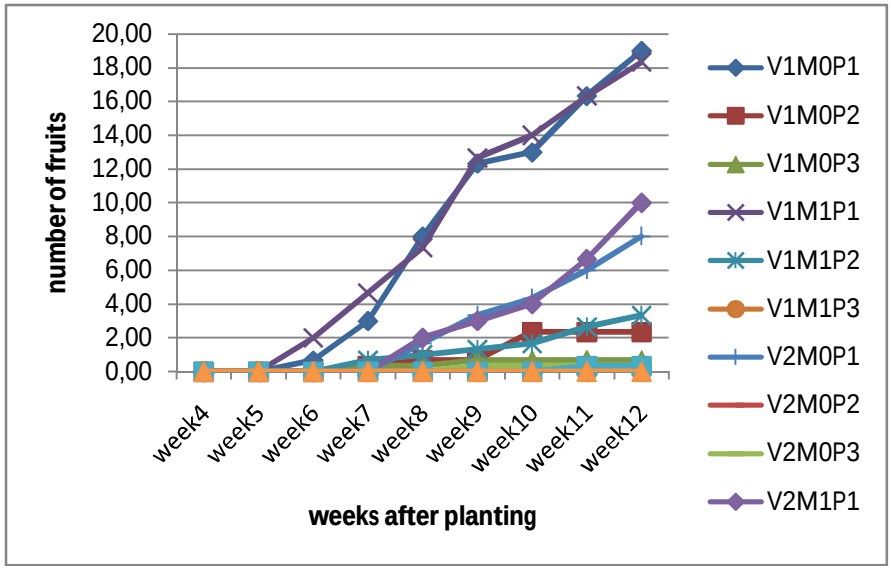

Figure 2. Number of fruits in each treatments

3. Weight of fruit

Observation on fruit weight could only be done when the fruits were ready to be harvested. Red coloured fruits were harvested and its weight recorded. From the 12 treatments, only 6 treatments produced fruits that were ready to be harvested : V1M0P1, V1M0P3, V1M1P1, V1M1P2, V2M0P1 and V2M1P1 (figure 3).

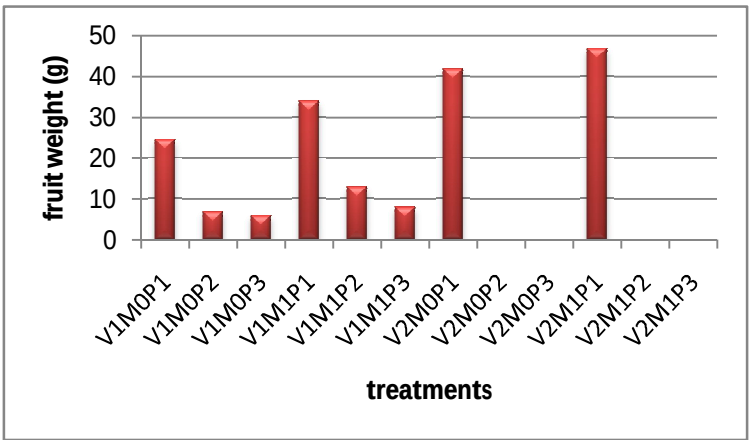

Figure 3. Weight of fruits in each treatments

The use of mycorrhiza sometimes does not affect the weight of fruit (Gunadi and Subhan, 2007). The addition of mycorrhiza mainly affects the roots of the plant by symbiosis to increase the area for water and nutrients absorption. The largest respond of mycorrhizal symbiosis must be in the roots which can be observed from the difference in root length (figure 7).

a)  b)  c) 

Figure 4. Fruits from different treatments : (a)V1M0P1, (b) V1M0P2 dan (c) V1M0P3

A less frequency of watering, caused a smaller fruit size in variety Revalina (V1) and can be seen from the reduced fruit weight (figure 3). Smaller fruits is caused by the lack of water that can be used for photosynthesis. The second variety (V2), Martha, did not produce many fruits. Only one fruit were harvested in week-12 for treatments V2M0P1 and V2M1P. The larger fruit of Martha can be the cause that not many fruits can be produced in water stressed condition. To produce larger fruits, more photosynthate must be produced. When water is restricted, the photosynthesis must not be optimum to produce fruits that are potentially larger in size.

a)  b) 

Figure 5. Fruits obtained from V2: (a)V2M0P1, (b) V2M1P1

4. Number of Leaves

There was no significant difference in the number of leaves between the different treatments of mycorrhiza. The result showed that the treatment with the most effect was the different in the watering treatment. Plants that were watered every day had more leaves compared to those watered every 7 and 14 days (figure 6). This shows that water is very important in the growth and development of leaves and limited water cause a significant effect in the growth of leaves of tomatoes.

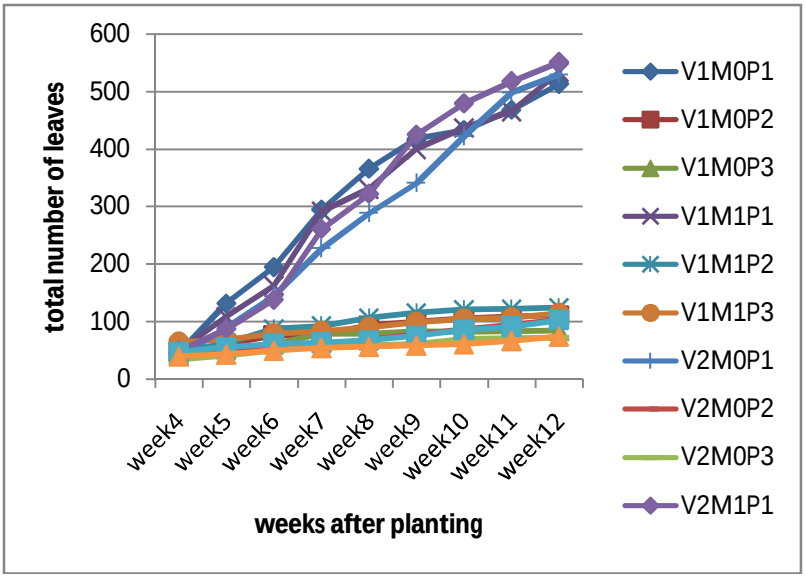

Figure 6. Number of leaves in each treatments

From Analysis of Variance (ANOVA), the difference between treatments can be observed between the watering treatments both between variety and between mycorrhizal treatments. A significant difference was found between watering treatments and not between mycorrhizal treatments. This shows that the addition of *Glomus* spp. did not affect significantly the growth of tomato plants especially on the growth of leaves. There are several isolates of mycorrhiza that do not affect the number of leaves such as *Gigaspora sp, G. manihotis, Glomus sp* (Rohayati, 1999 *cit.*, Sitrianingsih, 2010).

A siginificant result between the two different variety of tomato shows that each variety contributes to the effect in the development of leaves. Although the amount of water available for the plants is important, the effect of each genotype also played a significant part in the development of the leaves. The ability of each variety to use available water for photosynthesis can be different due to the adaptability of each variety on different stress environment. The different in the genetic potential of each variety can also effect in the ability of using the available water for the development of vegetative and generative parts.

Table 4. ANOVA for number of leaves

Variable	df	Sum of squares	Mean square	F value	Pr > F
Variety	1	18860.21	18860.21	18.96	0.0002
Mycorrhiza	1	1289.83	1289.83	1.30	0.2660
Watering	2	1489442.56	744721.28	748.75	<0.0001
Interaction (V*M*P)	7	2846.96	406.71	0.41	0.8873

Table 5. DMRT for variety effect on number of leaves

Perlakuan	Rerata Jumlah daun
V1	264.79^{A}
V2	218.94^{B}

Note : Values followed by the same letters (A,B,C) show no significant difference

5. Root Length

One of the mechanism used by plants to avoid drought stress is by morpho-physiological mechanism, by increasing its root length thus finding water away from the surface area (Djazuli, 2011). Increasing the roots volume and length are also a mechanism in surviving during dry condition (Jones *et al*., 1981 and Hamim *et al*., 1996 *cit*. Kisman, 2010). The result showed that mycorrhiza can change the morphology of tomato roots due to the association between plant and fungi and causing a change which enables plants to absorb water more efficiently. Mycorrhizal treatment caused an increase in root length and number of hair roots (figure 7). A longer root enables the plant to find water from areas that are deeper than plants without mycorrhiza. Mycorrhizal fungi are able to give various hormones such as auxin, cykoninin and giberellin to their host plants (Setiyadi, 1989 *cit*. Lucia *et al*., 1998). Those hormones are able to induce cell growth and other physiological processes thus increasing the transport of nutrients from soil to plant. Plant roots infected with mycorrhiza are slower in its aging process, thus able to absorb more nutrients and water from the soil.

a)  b) 

Figure 7. Roots of plants from different mycorrhizal treatments (a) V1M0P3 and (b)V1M1P3 at 12 weeks

Less watering frequency caused a change in the length and structure of tomato roots. This change occurred in both varieties. Watering everyday caused the roots to grow longer and more hair roots (figure 8). The plants were able to absorb more water and fulfill the needs for photosynthesis which then produce assimilates needed for growth and development. In both varieties roots were able to form at all water treatments, including watering every 2 weeks.

a)  b)  c) 

Figure 8. Roots of plants from treatments (a) V1M0P1 (b) V1M0P2 and (c)V1M0P3

From the ANOVA result, a significant result was observed for all variables (varieties, mycorrhiza and watering treatments). Genotypic potential can cause the difference in the root growth between the two varieties. Watering treatments caused a difference in root development due to the source of water available for growth. Mycorrizal treatments showed a significant effect in root length thus showing that the fungi caused an effective response which supports root growth especially during drought condition (watering treatment every 2 weeks).

Table 6. ANOVA for root length

Variable	df	Sum of squares	Mean square	F value	Pr > F
Variety	1	178.67	178.67	15.74	0.0006
Mycorrhiza	1	87.73	87.73	7.73	0.0104
Watering	2	1674.82	873.41	73.76	<0.0001
Interaction (V*M*P)	7	2358.14	336.88	29.67	<0.0001

CONCLUSION AND SUGGESTION

The addition of 4 gr/ plants of *Glomus* spp. as a mycorrhizal fungi showed significant difference on the development of tomato plants especially on root length. The effect of watering treatments gave the most significant result in most of the parameters. The number of flowers, initiation of flowering, number of fruits, weight of fruits, number of leaves and root length were all affected by the different watering treatments. Genotypic potential of each tomato varieties used in this experiment only caused a significant difference on number of fruits, weight of fruits and root length, while the addition of mycorrhizal fungi only caused a significant difference on root length. Further research must be carried out to further observe the effect of mycorrhizal fungi, but using a combination of inorganic fertilizers containing N, P and K to increase the amount of nutrients absorption from the soil. The effects of genotype on the infection of mycorrhiza can be further studied to observe the interaction at molecular level between fungi and host plant.

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